Analysis of CWSI as a Tool to Quantify Drought Stress Tolerance within Bi-Parental Populations of Winter Rye

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Introduction

Drought stress
- Annually, diurnally and spatially variable
- Large G*E interactions in yield production
- Low heritability of drought stress tolerance in yield based selection on drought stress

Canopy temperature
- ↑ drought stress ↓ transpiration ↑ canopy temperature
- Sensitive and specific indicator of drought stress
- Influenced by physiological plant criteria and environmental factors
- Selection criterion for drought and heat tolerance?
Introduction

Typical breeders experiments
- Large number of genotypes (n > 200)
- Few replications
- Large block size

Approaches to measure canopy temperature in breeding nurseries

<table>
<thead>
<tr>
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<th>Tractor based</th>
<th>Aerial image</th>
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<tbody>
<tr>
<td>All plots at same time</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Boundary conditions at each plot</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Wind independent</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Measurement cost</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Measurement duration</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Daily time courses measurable</td>
<td>-</td>
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Materials and Methods

Experimental setup

- 8 environments:
  - Years: 2
  - Sites: 2
  - Treatments: irrigated, rainfed
- 2 replications
- 240 inbreed lines and hybrids of rye
- 960 plots (5m²) per site
- Splitplot design

Experimental Locations Wohlde and Petkus (GNU Wikipedia, 28.5.2013)
Measurement system

Tractor based measurement system
- Georeferenced, 1Hz
  → 8 measurements per plot

Calculations
- Crop Water Stress Index
  \[ CWSI = \frac{T_{\text{crop}} - T_{\text{min}}}{T_{\text{max}} - T_{\text{min}}} \] (Jackson et al. 1988)
- Relative yield
  \[ Y_{\text{rel}} = \frac{Y_{\text{Rainfed}}}{Y_{\text{Irrigated}}} \]
Experimental setup

Experimental Setup Wohlde 2011.
Canopy temperature measurements for 5-30-2011 are shown as points.

Canopy temperature measurements assigned to corresponding test plots
Yield and relative Yield in Wohlde 2011 and 2012

![Box plots comparing yield and relative yield between rainfed and irrigated conditions in Wohlde 2011 and 2012.](image)
CWSI measurements in Wohlde 2011 and 2012

- Rainfed
- Irrigated

Wohlde 2011
- 05-12-11
- 05-25-11
- 05-30-11

Wohlde 2012
- 05-31-12
- 06-05-12
- 06-15-12
CWSI measurements in Wohlde 2011 and 2012

Rainfed
Irrigated

Wohlde 2011
Wohlde 2012

05-30-11
Correlation of CWSI vs. relative yield

Variance can have several reasons:
- Genotypic differences
- Soil differences within blocks
- Time course of ambient factors throughout the measurement

adj. $R^2 = 0.30$
Time course of canopy temperature

Time course of temperature measurement in Wohlsde 5-30-2011
Time course of canopy temperature

Time course of temperature Measurement in Wohld 5-30-2011
Time course of canopy temperature

Net radiation (W m$^{-2}$)

$T_{\text{Air}}$ (°C)

$T_{\text{Crop}}$, $T_{\text{Air}}$ (°C)

Time course of temperature Measurement in Wohlde 5-30-2011
Time course of canopy temperature
Time course of canopy temperature

![Graph showing the time course of canopy temperature for rainfed and irrigated genotypes. The x-axis represents time from 06:00 to 21:00, and the y-axis represents temperature in °C. The graph compares rainfed and irrigated conditions for Genotype 1.]
Time course of canopy temperature

[Graph showing the time course of canopy temperature for different genotypes and irrigation treatments.]
Correction of CWSI for diurnal trend

\[
\text{adj.} R^2 = 0.30
\]

\[
\text{adj.} R^2 = 0.45
\]
Correction of CWSI for diurnal trend

adj. $R^2 = 0.30$

adj. $R^2 = 0.33$
Influence of soil on relative yield

Apparent electric conductivity measured by EM38 (Wohlde 2011)

adj. $R^2 = 0.18$
Influence of soil on relative yield

adj. $R^2 = 0.18$

adj. $R^2 = 0.33$
Transferability of genotypic drought effects

\[ \frac{Y_{\text{rainfed}}}{Y_{\text{irrigated}}} (-) \text{ Wohlde 2011} \]

\[ \text{corrected CWSI} (-) \text{ Wohlde 2011} \]
Transferability of genotypic drought effects

Year to year correlation $Y_{rel} \sim \text{CWSI}$ is weak

Different mechanisms may be decisive for CWSI signal

– Rooting depth
– Rooting velocity
– Stomatal reaction
– Heat stress tolerance
Conclusion and Outlook

- Tractor based measurements of canopy temperature give accurate and reliable results.
- CWSI measured on certain days correlates to relative yield.
- Due to large block sizes genotypic characteristics are confounded by weather and soil variability.
- To correlate CWSI to certain genotype specific traits a thorough analysis of repeated measurements is needed (Covariance analysis, parameter estimation in dynamic crop model).
Thank you for your attention!